REMARKS/ARGUMENTS

Reconsideration of the above-identified application, as herein amended, is respectfully requested.

Status of Claims

Claims 1, 3, 5-16 and 21-24 are now pending in the application, with claim 1 being the only independent claim. Claims 1 and 16 have been amended. Claims 2 and 4 have been canceled, without prejudice.

Overview of the Office Action

Claims 1, 3, 6-16, 21, 23 and 24 stand rejected under 35 U.S.C. §102(e) as anticipated by U.S. Patent No. 6,504,301 (*Lowery*).

Claims 5 and 22 stand rejected under 35 U.S.C. §103(a) as unpatentable over *Lowery*.

Summary of Subject Matter Disclosed in the Specification

The following descriptive details are based on the specification. They are provided only for the convenience of the Examiner as part of the discussion presented herein, and are not intended to argue limitations which are unclaimed.

The present specification discloses a light source 1 having at least one LED 2 for emitting a primary radiation 4 and at least one luminescence conversion body 3 for converting the primary radiation 4 into a secondary radiation 5. The luminescence conversion body 3 is a polycrystalline ceramic body which itself acts partly or completely as luminescent material by virtue of at least part of the base material, which forms the ceramic body, being activated by a dopant. The ceramic body is formed from base crystallites, has a ceramic density of about 90%, and is translucent to both the primary radiation and the secondary radiation. *See* Fig. 1 and paragraphs [0011], [0017], [0043] and [0044] of the published specification.

A ceramic body is a unitary body sintered together from individual crystallites, rather than discrete particles dispersed in a medium such as an epoxy resin (*see*, *e.g.*, paragraph [0011] of the published specification).

Allowability of the Claims

Independent Claim 1

Independent claim 1 has been amended to include the subject matter of claims 2 and 4 (both of which are now canceled) and a feature of claim 16. Amended claim 1 accordingly now recites (I) the base material of the ceramic body being base crystallites, that (II) the ceramic body has a ceramic density of above 90%, and that (III) the ceramic body is translucent to both the primary radiation and the secondary radiation.

These amendments to claim 1 do not raise any new issues that would require further consideration and/or search by the Examiner.

Applicants submit that amended claim 1 is not anticipated by *Lowery* because *Lowery* does not disclose, either expressly or inherently, each and every element as set forth in amended claim 1. In particular, *Lowery* fails to disclose, teach or suggest the above-highlighted limitations of amended claim 1.

Lowery relates to an LED package 20, which includes a plurality of LED dies 22, 24 and a fluorescent plate 52 (*see* Fig. 2; col. 4, lines 14-23; col. 6, lines 6-8 of *Lowery*). The fluorescent plate 52 is used to cause the output light generated by the LED package 20 to duplicate natural white light (*see* Abstract of *Lowery*).

According to *Lowery*, the fluorescent plate 52 can be made of soft, optically clear, silicone rubber or other optically transparent materials such as polycarbonate or acrylic. In addition, the fluorescent plate 52 contains a phosphor material. For example, *Lowery* explicitly teaches that the fluorescent plate 52 may contain gadolinium doped, cerium (Ce) activated yttrium aluminum garnet (YAG) phosphor grains. *See* col. 6, lines 6-24 of *Lowery*. Thus, it is clear that in *Lowery*, the "base material" of the fluorescent plate 52 is silicon rubber, polycarbonate or acrylic; YAG phosphor grains are not used as the base material of the fluorescent plate 52.

Furthermore, in *Lowery*, when YAG phosphor grains are used, they are merely dispersed in the fluorescent plate 52. *Lowery* does not teach or suggest subjecting YAG phosphor grains to a sintering process to form a polycrystalline ceramic body, as in applicants' claims. The mere fact that YAG phosphor grains are described as present in the plate 52 of *Lowery* does not constitute a teaching or suggest that such YAG grains be sintered together to form a polycrystalline ceramic body. On the contrary, since *Lowery* discloses that the base material of the fluorescent plate 52 is silicon rubber, polycarbonate or acrylic, and that YAG phosphor grains are merely dispersed in the fluorescent plate 52, *Lowery* actually teaches away from sintering YAG phosphor grains together to form a polycrystalline ceramic body as in applicants' claimed light source.

Therefore, contrary to the Examiner's interpretation, *Lowery* does not disclose, teach or suggest that the luminescence conversion body is a polycrystalline ceramic body with a base material, the base material being base crystallites, as is now expressly recited in amended claim 1.

In addition, since as discussed above the base material of the fluorescent plate 52 is silicon rubber, polycarbonate or acrylic, and YAG phosphor grains are merely dispersed in the fluorescent plate 52 instead of being sintered together to form a polycrystalline ceramic body, *Lowery* does not disclose, teach or suggest a ceramic body that has a ceramic density of above 90%, as is now expressly recited in amended claim 1.

Moreover, since *Lowery* explicitly teaches that the fluorescent plate 52 is "optically transparent" (*see* col. 3, lines 1 and 2 of *Lowery*), and because a ceramic body of sintered together crystallites cannot be transparent by virtue of the interaction between light and the crystallite surfaces, the fluorescent plate 52 of *Lowery* cannot be formed of "base crystallites", as recited in claim 1. Applicants' claimed luminescence conversion body is translucent, not transparent. *Lowery* does not disclose, teach or suggest a luminescence conversion body having a ceramic body which is translucent to at least one of the primary radiation and the secondary radiation, as is now expressly recited in amended claim 1. Needless to say, "transparent" is not the same as "translucent."[1]

Thus, that the fluorescent plate 52 of *Lowery* is optically transparent itself evidences that the fluorescent plate 52 is not a "polycrystalline ceramic body", since a ceramic body cannot be transparent due to interaction of light rays with the surfaces of the base crystallites.

In view of these differences, withdrawal of the 35 U.S.C. §102(e) rejection of claim 1 is deemed appropriate and respectfully requested.

The utilized base material taught by *Lowery*, such as silicon rubber or acrylic, is sensitive to ultraviolet radiation and is therefore not as thermally and photo-chemically stable as is ceramic. Like the epoxy resin discussed in paragraph [0006] of the published specification of the present application, the transmissivity of the fluorescent plate 52 of *Lowery* will accordingly deteriorate over time as the fluorescent plate 52 is exposed to ultraviolet radiation emitted from the LED dies 22, 24. A ceramic conversion body thus presents advantageous functionality and utility over the fluorescent plate 52 of *Lowery*. Applicants therefore submit that the above-discussed differences between amended claim 1 and the teachings of *Lowery* clearly and patentably distinguish the subject matter of amended claim 1 thereover under 35 U.S.C. §103(a).

---

[1] In this regard, the Examiner's attention is respectfully directed to the enclosed excerpt from a book entitled "The High-Pressure Sodium Lamp," which excerpt discusses the difference between "transparent" and "translucent" and the ceramic density.

Dependent Claims 3, 5-16 and 21-24

Claims 3, 5-16 and 21-24 depend, either directly or indirectly, from independent claim 1, and each is accordingly deemed to be allowable therewith.

These dependent claims also include features which serve to still further distinguish the claimed invention over the prior art of record.

Conclusion

Based on the foregoing, applicants submit that the present application is now in full and proper condition for allowance. Prompt and favorable action to this effect, and early passage of this application to issue, are respectfully solicited.

Should the Examiner have any comments, questions, suggestions or objections, he is respectfully requested to telephone the undersigned in order to facilitate early resolution of any outstanding issues.

It is believed that no fees or charges are required at this time in connection with the present application. However, if any such fees or charges are required at this time, they may be charged to our Patent and Trademark Office Deposit Account No. 03-2412.

Respectfully submitted,

COHEN, PONTANI, LIEBERMAN & PAVANE LLP

By ______________________________

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Dated: January 3, 2007

THE HIGH-PRESSURE SODIUM LAMP

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and
ir J.A.J.M. van Vliet

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Preface

The purpose of this book is to outline the principles on which the design of high-pressure sodium discharge lamps is based and to leave the reader with a better understanding of both the background to and the application of these principles.

The book is addressed to research workers, students and development engineers engaged in the study of gas discharges in general and high-pressure sodium discharges in particular.

The emphasis throughout is on the physical aspects of the discharge, concentrating in the main on work carried out in the seventies and the early eighties. This work followed on from the early development work on lamp materials that took place in the beginning of the sixties. The renewed interest in the chemical and technological aspects of the high-pressure sodium discharge lamp coincides with the current development of low-wattage and improved-colour lamps. Because these aspects are still in the development stage, they have been covered somewhat less extensively. An exhaustive treatment of the applications open to the high-pressure sodium lamp is outside the scope of this book.

Chapter 1 provides an introduction to the high-pressure sodium lamp and examines its most important basic features in comparison with other discharge lamps.

Chapter 2 deals in general terms with the power balances and spectra of typical high-pressure sodium lamps and so provides an insight into the energy conversion and the luminous efficacy aspects of these lamps.

High-pressure sodium lamps are generally based on a discharge in a mixture of sodium, mercury and xenon, and this makes a theoretical description rather difficult. To simplify matters, therefore, a high-pressure sodium discharge without these buffer gases is first considered. The spectrum and the power balance of such a so-called pure sodium discharge are discussed in more detail in Chapter 3 and 4 respectively.

In Chapter 5 attention is centred on the influence that the buffer gases mercury and xenon have on the field strength, plasma temperature, radiant power and spectrum of a high-pressure sodium discharge.

Chapter 6 deals with the ignition of the HPS lamp and its stabilisation on

the usual 50 Hz mains-frequency supply. The special cases for high-frequency and pulse current operation are treated in Chapter 7.
Chapters 8 and 9 examine the general properties of the discharge-tube material, the ceramic-to-metal seal and the electrodes.
Finally, Chapter 10 provides guidance on lamp design, the material presented in the earlier chapters being used to shape a design approach.

The authors are indebted to Dr M. Koedam, director of the Lighting Division within the Nederlandse Philips Bedrijven B.V. in Eindhoven, for his support in making the publication of this book possible. We also wish to thank Prof. Dr A.A. Kruithof for his careful reading of the manuscript, and many of our colleagues in the Philips Lighting Division and the Company's Research Laboratories for their invaluable comments. Finally, our thanks are also due to Mr A. Kortman, who produced the many drawings, and to Mr D.L. Parker for his invaluable assistance in preparing the manuscript.

J.J. de Groot　　　　　　　　Eindhoven
J.A.J.M. van Vliet　　　　　　May 1985

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into a curved or distorted path. The observation that modes with a saddle on the axis of the tube do not disturb the path of the discharge is in agreement with the observations of Strickler and Stewart (1963).

Disturbances of the discharge path by longitudinal acoustic resonances cannot be explained with the help of pressure distributions, because a constant phase relation cannot be found.

In conclusion, it can be said that the occurrence of acoustic resonances with visible arc distortions can be described rather well theoretically. The designer of HPS lamps destined for high-frequency or pulse operation can avoid the troublesome acoustic resonances by a proper choice of the discharge tube dimensions, gas composition and pressure. However, the higher the gas pressure chosen, the smaller are the resonance-free bands and the higher the frequency below which acoustic resonances can be excited. The ballast designer should therefore carefully choose the supply frequency when employing electronic control gear in combination with existing HPS discharge lamps.

Chapter 8

Discharge-Tube Material and Ceramic-to-Metal Seal

The discharge-tube material and the gas-tight seal between the ceramic discharge tube and the metal current feedthrough play an essential role in determining various properties of the HPS lamp with its hot, chemically aggressive sodium vapour. As already described in the Introduction (Secs 1.1.1 and 1.1.2) the development of a light-transmitting, sodium-resistant discharge-tube material was one of the crucial points for the realisation of an HPS lamp. The material properties of the discharge-tube material (Sec. 8.1) and the ceramic-to-metal seal (Sec. 8.2), as well as the manufacturing techniques employed, together ensure that the completed lamp has an optimum performance with respect to lifetime, luminous efficacy, etc.

8.1 Discharge-Tube Material

The discharge tube of the HPS lamp must meet the following requirements:

- have a high light transmittance
- be gas-tight
- be resistant to the aggressive sodium vapour for vapour pressures between 5 kPa and 100 kPa and for temperatures between 1000 K and 2000 K
- have a high electrical resistivity at these temperatures
- have a low evaporation rate at these temperatures
- possess sufficient mechanical strength and resistance to thermal shocks when the lamp is switched on and off.

Sec. 8.1.1 describes the properties of polycrystalline alumina and the process of making it; Sec. 8.1.2 deals with alternative ceramics and sapphire. Sec. 8.1.3 gives a review of the optical properties of alumina, and Sec. 8.1.4 discusses other physical and chemical properties of this material.

8.1.1 Polycrystalline Alumina

Sintered alumina, the most important properties of which are summarised in table 8.1, met all the requirements for a discharge-tube material listed above, except that of a high light transmittance. Then, between 1955 and

Table 8.1 Properties of densely sintered polycrystalline alumina (PCA). Unless stated otherwise the data are taken from Gitzen (1970) or Goldsmith et al. (1961)

Constitution	alpha alumina (α-Al_2O_3)
Crystal structure	hexagonal
Melting point	2324 K (2051 °C)
Theoretical density	3986 kg m^{-3}
Expansion coefficient at 1200 K	8.1 10^{-6} K^{-1} (polycrystalline) 7.8 10^{-6} K^{-1} (perpendicular to c-axis) 8.7 10^{-6} K^{-1} (parallel to c-axis)
Thermal conductivity* (1500 K)	12 W m^{-1} K^{-1}
Specific heat (1500 K)	1.31 10^3 J kg^{-1} K^{-1}
Resistivity (1000 K)	$10^8 - 10^{10}$ Ω m
(1500 K)	$10^6 - 10^8$ Ω m
Ordinary refractive index at 590 nm	1.768

* After Forman (1973).

1957, a process was found for sintering alumina densely enough for it to become translucent. This was done by adding 0.2 per cent by weight of magnesia (MgO) to pure Al_2O_3 (Cahoon and Cristensen, 1955; Coble and Burke, 1961; Coble, 1962).

The process of making polycrystalline alumina involves three steps. First comes the production of a very pure (99.99 per cent) alumina powder. This can be made by calcination of alum (Al, $NH_4(SO_4)_2$ aq), giving 5 per cent γ-Al_2O_3 with a mean particle size of 0.02 μm and 95 per cent α-Al_2O_3 with a mean particle size of 0.5 μm. Magnesia is then added to sinter the alumina to translucency.

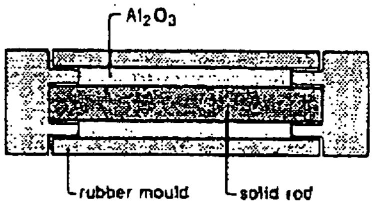

Figure 8.1 Schematic representation of the pressing process for alumina powder, in this case for a cylindrical tube (see figure 8.2a).

The second step is to give the alumina (mixed with a binder) the desired geometrical shape. This can be done, for example, by compressing the alumina powder isostatically in the annular space between a hollow, cylindrical rubber mould and a solid, cylindrical rod (figure 8.1) to produce a single cylindrical tube. Alternatively, the alumina, in the form of a paste with binder, can be extruded, or forced through a circular opening, the continuously-emerging cylinder then being cut into tubes of the desired length. This extrusion process is by far the faster of the two processes described. Non-cylindrical discharge tubes can be formed if, in the isostatic pressing process, a dummy of low-melting material (wax, tin or wood metal) in the desired shape is used instead of the cylindrical rod (Carlson, 1975). The dummy is afterwards removed by heating. This is the so-called lost-wax process. Another way of obtaining complex-shaped tubes (figure 10.21) is to employ a blowing technique to expand the extruded cylindrical tube into the shape of a surrounding cavity, a fluid pumped under pressure into the cylindrical tube being used for this purpose (Furuta *et al.*, 1983).

The third step is the sintering process. After pre-sintering the tubes in air at about 1550 K to remove the binder, the final sintering, lasting several hours, takes place in hydrogen at about 2100 K. During the sintering process, the density of the alumina increases and the tube shrinks to about 70 per

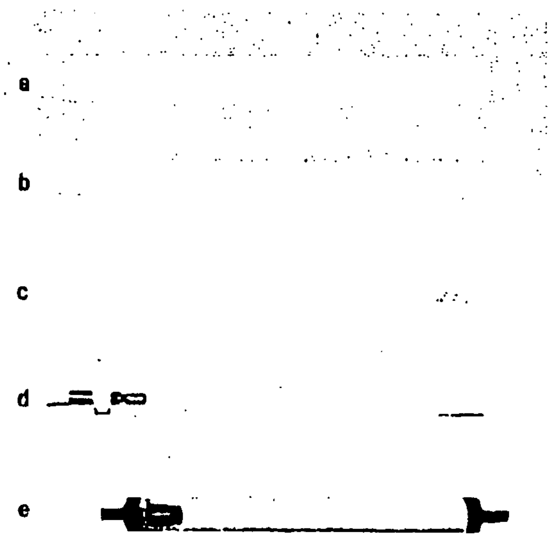

Figure 8.2 Various stages in the manufacture of a polycrystalline alumina (PCA) discharge tube for a 400 W HPS lamp:
a) cylindrical tube formed by pressing the alumina powder
b) tube and plug after pre-sintering
c) tube after the complete sintering process
d) alumina tube and electrode with its feedthrough construction
e) complete discharge tube

cent of its former size in every direction (compare tubes a and c in figure 8.2). In this way a polycrystalline material with a crystal size between 10 and 100 μm is obtained. The shrinkage can be used to sinter an electrode-feedthrough plug into place at the end of the discharge tube (tubes b and c in figure 8.2).

The density of the alumina after the sintering process is in excess of 99.5 per cent of its x-ray density (theoretical value as calculated from lattice parameters), which means that the relative volume of the pores is less than 0.5 per cent. In the process of making densely-sintered polycrystalline alumina (PCA), the addition of the correct amount of magnesia plays an essential role as it inhibits discontinuous grain growth and increases the density near to its theoretical limit (figure 8.3). The result is that pores are not trapped inside the grains (figure 8.4), but can disappear by diffusion of vacancies. So a material is produced that transmits light reasonably well, although very diffusely (Peelen, 1977).

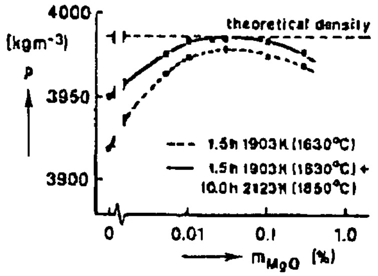

Figure 8.3 The density ρ of the sintered alumina as a function of the magnesia content m_{MgO} (given in weight per cent) for two sintering methods. (Peelen, 1977)

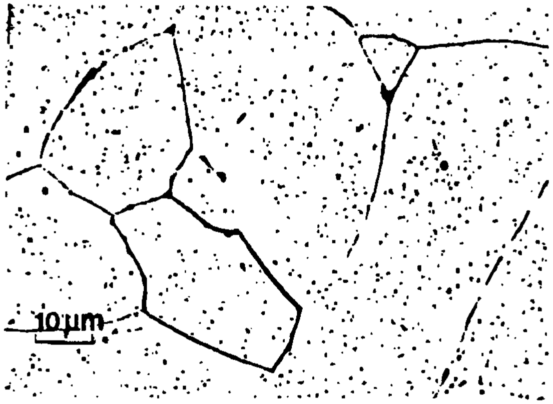

Figure 8.4 Undoped alumina sintered for 10 hours at 2123 K (1850°C), showing discontinuous grain growth. Most of the pores are trapped inside the grains; they are visible in the photograph as black dots. (Peelen, 1977)

PCA scatters the light passing through it, and so, in contradistinction with sapphire, which is transparent, this material is translucent (see figures 8.5 and 8.6). Names for the polycrystalline alumina are derived from this feature: Lucalox (Registered Trade Mark of General Electric – USA) from translucent aluminium oxide, and DGA from the Dutch words *doorschijnend gasdicht aluminium oxide*, meaning translucent gas-tight aluminium oxide.

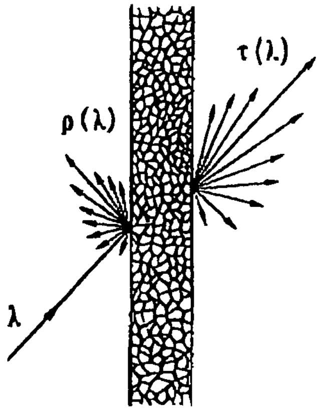

Figure 8.5 Schematic representation of the light scattering produced by a slice of porous polycrystalline alumina; λ indicates the incident radiation, τ(λ) the transmitted radiation and ρ(λ) the reflected radiation.

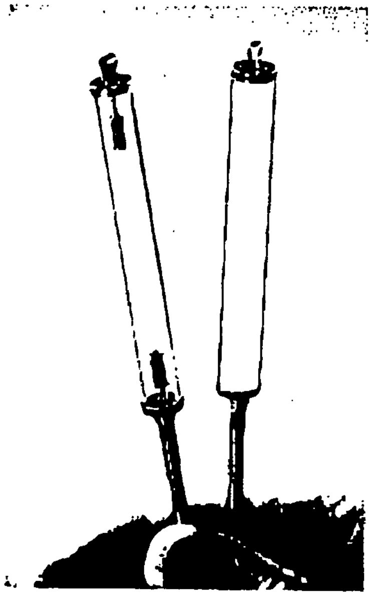

Figure 8.6 Photograph of (left) a sapphire and (right) a polycrystalline discharge tube, showing the difference between transparent and translucent materials. The electrodes are clearly visible through the transparent sapphire but not through the translucent polycrystalline alumina. (Rigden, 1965)

The light scattering is mainly the result of the residual porosity. This was shown by Peelen (1976, 1977), who employed another technique to sinter the alumina, namely hot-pressing. A high pressure is employed to deliver an extra driving force for sintering, and this allows the required density to be obtained at a lower temperature than is possible in the normal sintering process. The light scattering properties of hot-pressed alumina are quite different from those of normally-sintered alumina. The hot-pressed material can be described as transparent, while the normally-sintered material is translucent (see figure 8.7). The essential difference between the two materials is that the former has a much smaller mean grain size and pore size. The residual pores in the hot-pressed material have a diameter of about 0.2 μm; this is small compared to the wavelength of light. The pores in the normally-sintered alumina are about equal in size to the wavelength of light, namely around 1 μm and therefore they cause the strong scattering.

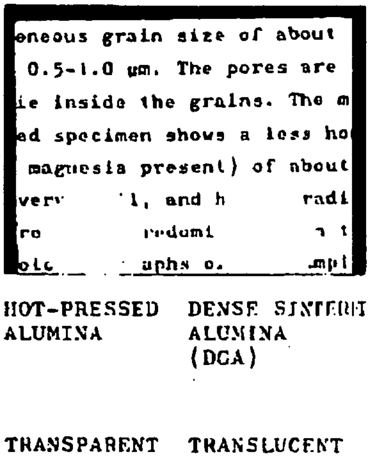
eneous grain size of about
0.5-1.0 µm. The pores are
ie inside the grains. The m
ed specimen shows a less ho
magnesia present) of about
HOT-PRESSED ALUMINA
DENSE SINTERED ALUMINA (DGA)
TRANSPARENT
TRANSLUCENT

Figure 8.7 Photograph showing two discs of polycrystalline alumina (hot-pressed and normally sintered) about 10 cm above a printed page. Only the text under the hot-pressed material is legible. (Peelen, 1976 and 1977)

Dopes are added to the alumina to obtain a very high density and a regular microstructure, so improving the optical and mechanical properties of the sintered material. Besides MgO, also CaO or Y_2O_3 and La_2O_3 may be added as extra dopes (Kobayashi and Kaneno, 1975; Prud'homme van Reine, 1983). Both dopes (added foreign compounds) and impurities (foreign compounds not intentionally added) may influence the material properties. Figure 8.8, for example, shows how a CaO dope alters the microstructure of the alumina. The dopes partly evaporate during the sintering process, the dope concentration decreasing with increase in applied temperature, particularly near to the surface. The dopes and impurities may be present in solid solution, segregated at the grain boundaries, and in second-phase particles.

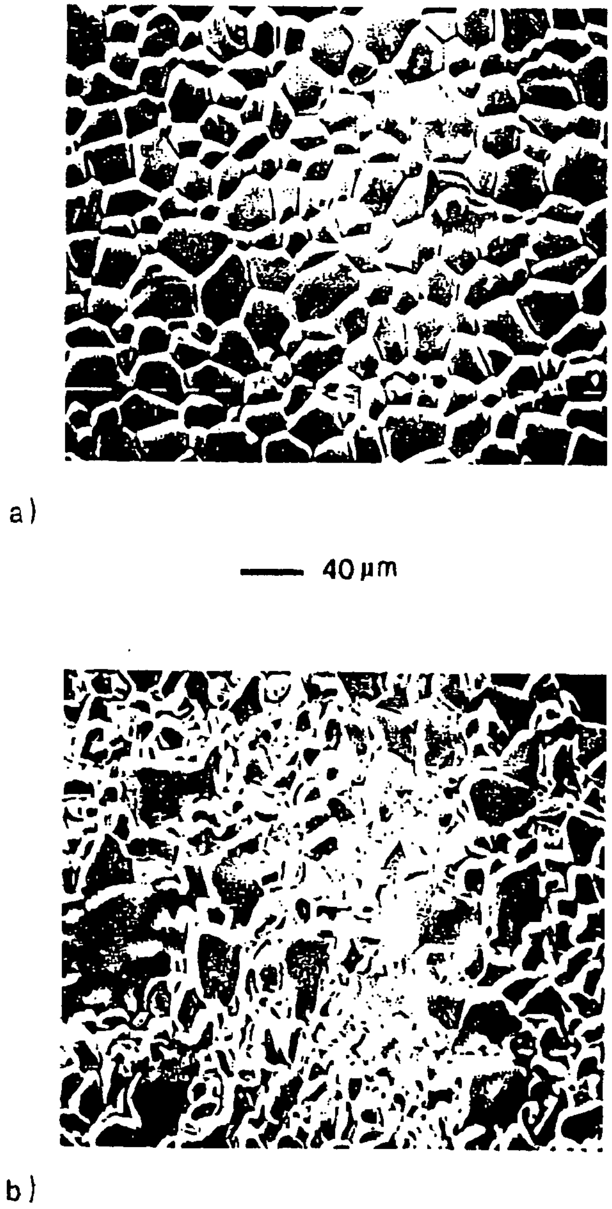

Figure 8.8 Polycrystalline alumina (a) without and (b) with CaO as extra dope, apart from the MgO. In the case of the extra CaO dope, a more irregular microstructure is visible.

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